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MANUFACTURING METHOD OF MOLECULAR FILM PATTERN, MOLECULAR FILM PATTERN,  
MANUFACTURING METHOD OF SEMICONDUCTOR DEVICE, SEMICONDUCTOR DEVICE,  
MANUFACTURING METHOD OF ELECTRO-OPTICAL DEVICE, ELECTRO-OPTICAL DEVICE,  
MANUFACTURING METHOD OF ELECTRONIC DEVICE, AND ELECTRONIC APPARATUS

#### Technical Field

The present invention relates to a molecular film and a molecular film pattern, both of which are formed on a surface of a substrate or on an underlying layer, and relates to manufacturing methods therefor. In addition, the present invention also relates to a semiconductor device and to an electro-optical device, both of which use the molecular film, the molecular film pattern, and the manufacturing methods therefor mentioned above, and relates to manufacturing methods for the devices mentioned above.

#### Background of the Invention

Among manufacturing steps of semiconductor devices or electro-optical devices, a photolithographic method has been used for a step of patterning a thin-film, which is one of important steps. A photolithographic method is capable of forming a highly fine pattern of the submicron order. In general, patterning using a photolithographic method is performed by the steps described below. First, a thin-film to be patterned is formed over the entire surface of a substrate. In addition, the formation of a resist film, exposure, development, rinsing, and the like are performed, thereby forming a resist pattern.

### Problems to be Solved by the Invention

Accordingly, a first object of the present invention is to efficiently form a molecular film pattern by using a molecular film having a superior photolytic property. A second object is to obtain a semiconductor device and an electro-optical device by using the molecular film, the molecular film pattern, and the manufacturing methods therefor described above, and a fourth object is to provide methods for manufacturing the semiconductor device and the electro-optical device described above.

A first method for manufacturing a molecular film pattern according to the present invention comprises a step of forming a molecular film by using a photolytic organic silicon compound, which contains an aromatic hydrocarbon group, as a starting material; and a step of irradiating the molecular film with a light. According to this method, since the

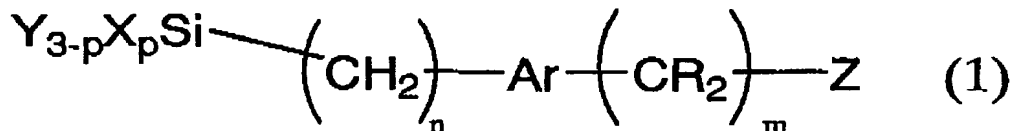
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A second method for manufacturing a molecular film pattern according to the present invention comprises a step of forming a molecular film by using an organic silicon compound as a starting material, the organic silicon compound having a chemical structure represented by the following formula (1); and a step of irradiating the molecular film with a light. According to this method, since the molecular film described above is formed of the organic silicon compound containing an aromatic hydrocarbon group which has high photoabsorption efficiency, a desired molecular film pattern can be easily obtained by performing light irradiation on the molecular film in accordance with a predetermined pattern shape. As the aryl (Ar) group in the formula (1), for example, there may be mentioned a phenyl group, a biphenyl group, a naphthyl group, an anthryl group, or a phenanthryl group. It may also be bonded to a major chain of a polymer via  $(CR_2)_n-2$  which is a substituent bonded to the aromatic hydrocarbon group.

[ Chemical 11 ]

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In the above formula, n, m, p, Ar, X, Y, and R are as follows:

n is an integer of 0 or more;

m is an integer of 0 or more;

p is an integer of 0 or more;

Ar is an aryl group;

R is a hydrogen atom or a fluorine atom;

X is a halogen group such as a chlorine group, an amino group, or an alkoxyl group;

Y is an alkyl group, an aryl group, or a hydrogen atom; and

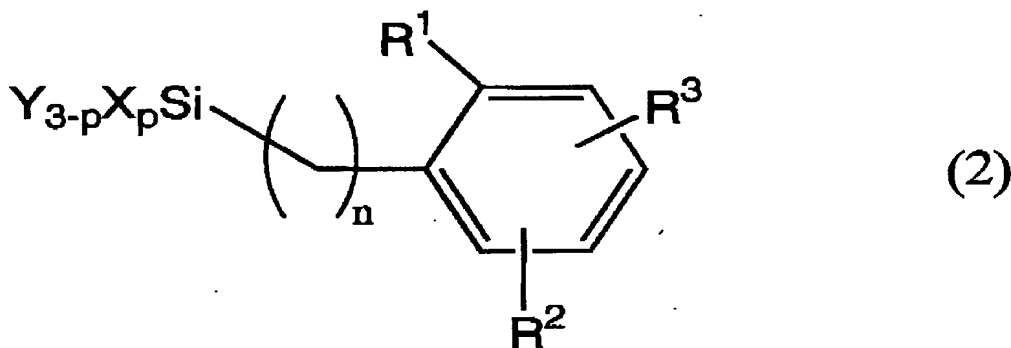
Z is an alkyl group, a perfluoroalkyl group, a silyl group, a cyano group, an amino group, or a thiol group.

A third method for manufacturing a molecular film pattern according to the present invention comprises a step of forming a molecular film by using an organic silicon compound as a starting material, the organic silicon compound having a chemical structure represented by the following formula (2); and a step of irradiating the molecular film with a light. According to this method, since the molecular film described above is formed of the organic silicon compound having a  $\pi$  electron system of the benzene structure which has high photoabsorption efficiency, a desired molecular film pattern can be easily obtained by performing light irradiation.

[Chemical 12]

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In the above formula,  $n$ ,  $p$ ,  $R^1$ ,  $R^2$ ,  $R^3$ ,  $X$ , and  $Y$  are as follows:

$n$  is an integer of 0 or more;

$p$  is an integer of 0 or more;

$R^1$  is a hydrogen atom, a halogen atom, a perfluoroalkyl group, a hydroxyl group, a thiol group, an amino group, an alkylamino group, an alkoxyl group, an alkyl group containing a hydroxyl group, an alkyl group containing a thiol group, an alkyl group containing an amino group, or an alkyl group containing an alkylamino group;

$R^2$  is a hydrogen atom, a halogen atom, a perfluoroalkyl group, a hydroxyl group, a thiol group, an amino group, an alkylamino group, an alkoxyl group, an alkyl group containing a hydroxyl group, an alkyl group containing a thiol group, an alkyl group containing an amino group, an alkyl group containing an alkylamino group, an organic silicon group, or an alkyl group containing an organic silicon group;

$R^3$  is a halogen atom, a perfluoroalkyl group, a hydroxyl group, a thiol group, an amino group, an alkylamino group, an alkoxyl group, an alkyl group containing a hydroxyl group, an alkyl group containing a thiol group, an alkyl group containing an amino group, an alkyl group

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containing an alkylamino group, an organic silicon group, an alkyl group  
containing an organic silicon group, an aryl group, or an alkyl group  
containing an aryl group;

X is a halogen group such as a chlorine group, an amino group, or an  
alkoxyl group; and

Y is an alkyl group or an aryl group.

A fourth method for manufacturing a molecular film pattern  
according to the present invention comprises a step of forming a  
molecular film by using an organic silicon compound as a starting  
material, the organic silicon compound having a chemical structure  
represented by the following formula (3); and a step of irradiating the  
molecular film with a light. According to this method, since the  
molecular film described above is formed of the organic silicon compound  
having a  $\pi$  electron system of the naphthalene structure which has high  
photoabsorption efficiency, a desired molecular film pattern can be  
easily obtained by performing light irradiation.

[Chemical 13]



R<sup>3</sup> is a hydrogen atom, a halogen atom, a perfluoroalkyl group, a hydroxyl group, a thiol group, an amino group, an alkylamino group, an

Y is an alkyl group or an aryl group.

[Chemical 14]





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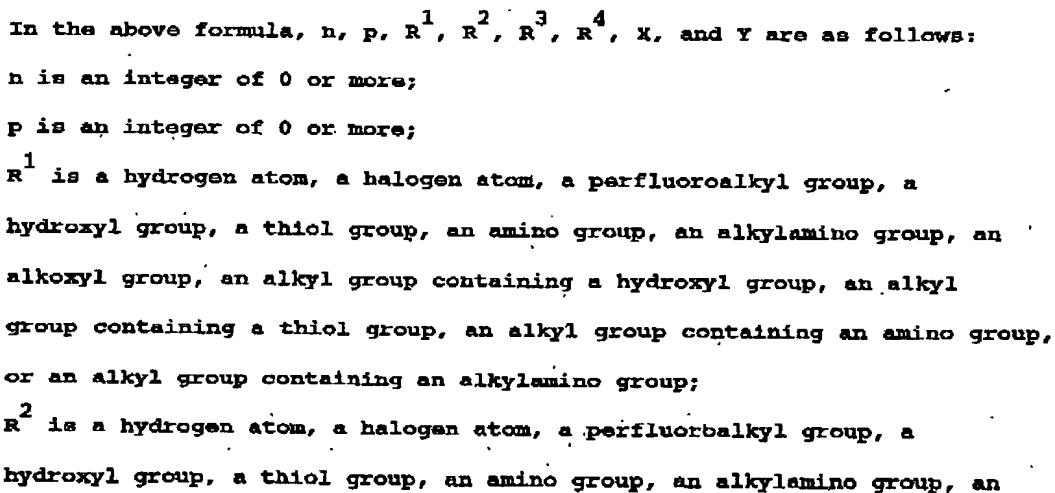
p is an integer of 0 or more;

R<sup>2</sup> is a hydrogen atom, a halogen atom, a perfluoroalkyl group, a hydroxyl group, a thiol group, an amino group, an alkylamino group, an alkoxy group, an alkyl group containing a hydroxyl group, an alkyl group containing a thiol group, an alkyl group containing an amino group, an alkyl group containing an alkylamino group, an organic silicon group, or an alkyl group containing an organic silicon group;

X is a halogen group such as a chlorine group, an amino group, or an alkoxy group; and

A sixth method for manufacturing a molecular film pattern according to the present invention comprises a step of forming a molecular film by using an organic silicon compound as a starting material, the organic

[Chemical 15]



Y is an alkyl group or an aryl group.

A seventh method for manufacturing a molecular film pattern according to the present invention comprises a step of forming a molecular film by using an organic silicon compound as a starting material, the organic silicon compound having a chemical structure represented by the following formula (5); and a step of irradiating the molecular film with a light. According to this method, since the

[Chemical 16]

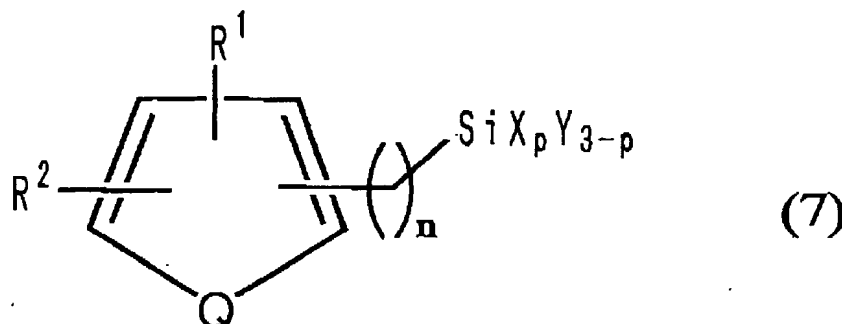


$R^2$  is a halogen atom, a perfluoroalkyl group, a hydroxyl group, a thiol

Y is an alkyl group or an aryl group.

An eighth method for manufacturing a molecular film pattern according to the present invention comprises a step of forming a molecular film by using an organic silicon compound as a starting material, the organic silicon compound having a chemical structure represented by the following formula (7); and a step of irradiating the molecular film with a light. According to this method, since the molecular film described above is formed of the organic silicon compound containing a conjugated electron system heterocyclic group, such as thiophene, pyrrole, or furan, which has high photoabsorption efficiency, a desired molecular film pattern can be easily obtained by performing light irradiation. In addition, since the organic silicon compound described above has a heteroatom having reactive functionality, such as a sulfur atom, a nitrogen atom, or an oxygen atom, which forms the heterocyclic ring, by performing appropriate chemical treatment, additional functions may be further provided for the molecular film pattern.

[Chemical 17]



In the above formula,  $n$ ,  $p$ ,  $R^1$ ,  $R^2$ ,  $X$ ,  $Y$ , and  $Q$  are as follows;

$n$  is an integer of 0 or more;

$p$  is an integer of 0 or more;

$R^1$  is a hydrogen atom, a halogen atom, a perfluoroalkyl group, a hydroxyl group, a thiol group, an amino group, an alkylamino group, an alkoxy group, an alkyl group containing a hydroxyl group, an alkyl group containing a thiol group, an alkyl group containing an amino group, or an alkyl group containing an alkylamino group;

$R^2$  is a halogen atom, a perfluoroalkyl group, a hydroxyl group, a thiol group, an amino group, an alkylamino group, an alkoxy group, an alkyl group containing a hydroxyl group, an alkyl group containing a thiol group, an alkyl group containing an amino group, an alkyl group containing an alkylamino group, an organic silicon group, an alkyl group containing an organic silicon group, an aryl group, or an alkyl group containing an aryl group;

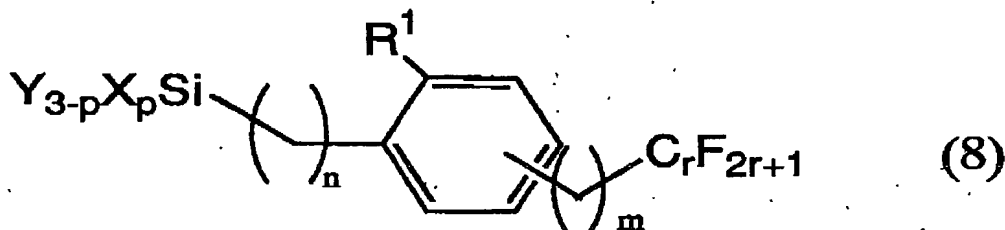
$X$  is a halogen group such as a chlorine group, an amino group, or an alkoxy group;

Y is an alkyl group or an aryl group; and

Q is a nitrogen (N) atom, an oxygen (O) atom, or a sulfur (S) atom, each having a hydrogen atom or an alkyl group.

A ninth method for manufacturing a molecular film pattern according to the present invention comprises a step of forming a molecular film by using an organic silicon compound as a starting material, the organic silicon compound having a chemical structure represented by the following formula (8); and a step of irradiating the molecular film with a light. According to this method, since the molecular film described above is formed of the organic silicon compound having a benzene ring provided with a fluoroalkyl group which has a superior liquid-repellent property, this molecular film has superior photoreactivity and a high liquid-repellent property. Accordingly, by performing light irradiation on this molecular film, a molecular film pattern having a different liquid-repellent property can be formed. In addition, in order to obtain a superior liquid-repellent property, the number of atoms of a carbon chain of a fluoroalkyl group is preferably three or more.

[Chemical 18]



In the above formula, n, m, r, p, R<sup>1</sup>, X, and Y are as follows:

n is an integer of 0 or more;

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m is an integer of 0 or more;

r is a positive integer;

p is an integer of 0 or more;

$R^1$  is a hydrogen atom, a halogen atom, a perfluoroalkyl group, a hydroxyl group, a thiol group, an amino group, an alkylamino group, an alkoxyl group, an alkyl group containing a hydroxyl group, an alkyl group containing a thiol group, an alkyl group containing an amino group, or an alkyl group containing an alkylamino group;

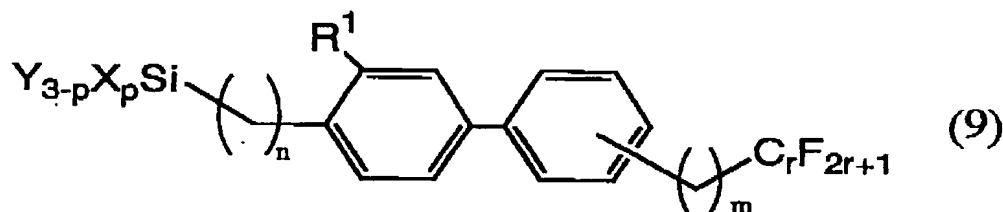
X is a halogen group such as a chlorine group, an amino group, or an alkoxyl group; and

Y is an alkyl group or an aryl group.

A tenth method for manufacturing a molecular film pattern according to the present invention comprises a step of forming a molecular film by using an organic silicon compound as a starting material, the organic silicon compound having a chemical structure represented by the following formula (9); and a step of irradiating the molecular film with a light. According to this method, since the molecular film described above is formed of the organic silicon compound, which has a fluoroalkyl group provided with a superior liquid-repellent property in addition to a  $\pi$  electron system of the biphenyl structure provided with high photoabsorption efficiency, when light irradiation is performed on this molecular film, a molecular film pattern having a different liquid-repellent property can be formed. In addition, in order to obtain a superior liquid-repellent property, the number of atoms of a carbon chain of a fluoroalkyl group is preferably three or more.



[Chemical 19]



In the above formula, n, m, r, p, R<sup>1</sup>, X, and Y are as follows:

n is an integer of 0 or more;

m is an integer of 0 or more;

r is a positive integer;

p is an integer of 0 or more;

R<sup>1</sup> is a hydrogen atom, a halogen atom, a perfluoroalkyl group, a hydroxyl group, a thiol group, an amino group, an alkylamino group, an alkoxy group, an alkyl group containing a hydroxyl group, an alkyl group containing a thiol group, an alkyl group containing an amino group, or an alkyl group containing an alkylamino group;

X is a halogen group such as a chlorine group, an amino group, or an alkoxy group; and

Y is an alkyl group or an aryl group.

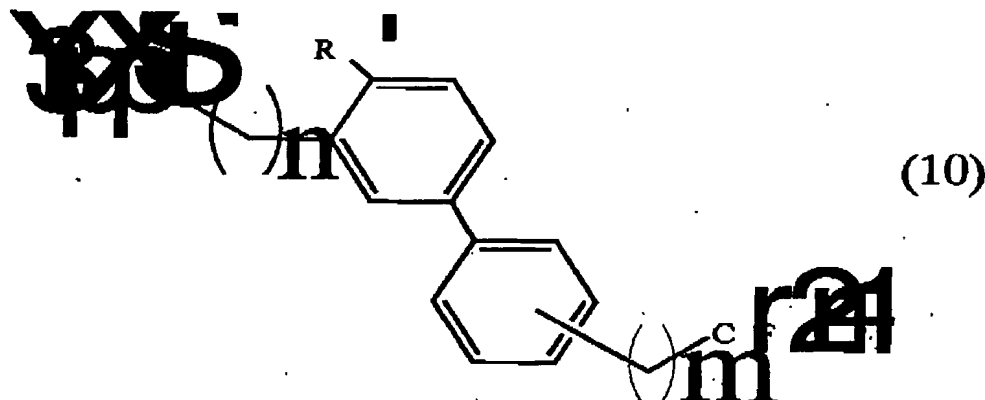
An eleventh method for manufacturing molecular film pattern according to the present invention comprises a step of forming a molecular film by using an organic silicon compound as a starting material, the organic silicon compound having a chemical structure represented by the following formula (10); and a step of irradiating the molecular film with a light. According to this method, since the

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molecular film described above is formed of the organic silicon compound, which has a fluoroalkyl group provided with a superior liquid-repellent property in addition to a  $\pi$  electron system of the biphenyl structure provided with high photoabsorption efficiency, when light irradiation is performed on this molecular film, a molecular film pattern having a different liquid-repellent property can easily be formed. In addition, in order to obtain a superior liquid-repellent property, the number of atoms of a carbon chain of a fluoroalkyl group is preferably three or more.

[Chemical 20]



In the above formula,  $n$ ,  $m$ ,  $r$ ,  $p$ ,  $R^1$ ,  $X$ , and  $Y$  are as follows:

$n$  is an integer of 0 or more;

$m$  is an integer of 0 or more;

$r$  is a positive integer;

$p$  is an integer of 0 or more;

$R^1$  is a hydrogen atom, a halogen atom, a perfluoroalkyl group, a

hydroxyl group, a thiol group, an amino group, an alkylamino group, an alkoxy group, an alkyl group containing a hydroxyl group, an alkyl group containing a thiol group, an alkyl group containing an amino group, or an alkyl group containing an alkylamino group;

X is a halogen group such as a chlorine group, an amino group, or an alkoxy group; and

Y is an alkyl group or an aryl group.

In a twelfth method for manufacturing a molecular film pattern according to the present invention,  $R^1$  of the organic silicon compound according to one of the methods for manufacturing the third to sixth and the ninth to eleventh molecular film patterns of the present invention is a perfluoroalkyl group. According to this method, the molecular film described above is formed of the organic silicon compound containing the perfluoroalkyl group at the ortho-position with respect to the organic silicon group. In this type of organic silicon compound, since a silicon atom and a fluorine atom having a high affinity thereto are spatially adjacent to each other, the attack of the fluorine atom to the silicon atom easily occurs, and hence, the photoreactivity or the photolytic property is improved. Accordingly, a molecular film pattern can be obtained by light irradiation for a short period of time.

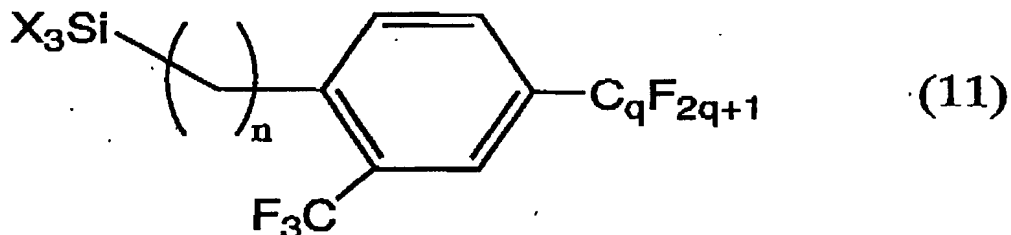
In a thirteenth method for manufacturing a molecular film pattern according to the present invention,  $R^1$  of the organic silicon compound according to one of the methods for manufacturing the third to sixth and the ninth to eleventh molecular film patterns of the present invention is a trifluoromethyl group. According to this method, the molecular

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film described above is formed of the organic silicon compound containing a trifluoromethyl group disposed at the ortho-position with respect to the organic silicon group. In this type of organic silicon compound, since a silicon atom and a fluorine atom having a high affinity thereto are spatially adjacent to each other, when photolytic reaction occurs, the photoreactivity or the photolytic property is improved by the assistance of the fluorine atom. Accordingly, the molecular film pattern can be obtained by light irradiation within a short period of time. In this method, as the organic silicon compound for forming this molecular film, a compound represented by the formula (11) or (12) is mentioned.

[Chemical 21]

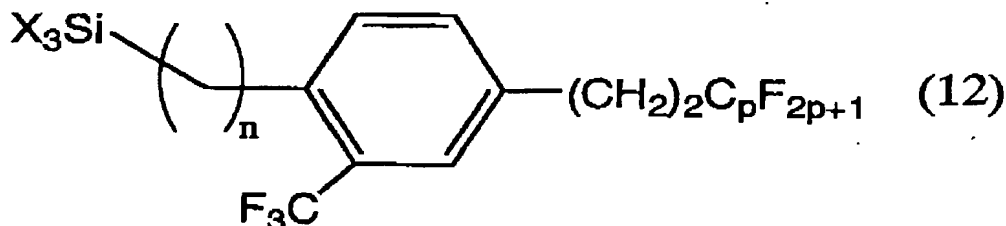


In the above formula, n and q are as follows:

n is an integer of 0 or more; and

q is an integer of 1 or more.

[Chemical 22]



In the above formula, n and p are as follows:

n is an integer of 0 or more; and

p is an integer of 1 or more.

In a fourteenth method for manufacturing a molecular film pattern according to the present invention, the thickness of the molecular film according to the method for manufacturing the molecular film pattern of the present invention is 3 nm or less. This molecular film has a thickness enough to modify the properties of the surfaces of the substrate or the underlying layer, and when the molecular film pattern is formed, high contrast of the surface functions or surface properties can be obtained.

A molecular film pattern of the present invention may be formed by one of the methods for manufacturing the molecular film patterns described above. Since the molecular film pattern described above is a molecular film pattern formed by patterning a molecular film having various functions such as a liquid-repellent property, surfaces with different functions are exposed in this molecular film pattern.

A method for manufacturing a semiconductor device of the present invention comprises a step of forming a molecular film pattern according to the manufacturing method for the molecular film pattern described

A method for manufacturing an electro-optical device of the present invention comprises a step of forming a molecular film pattern according to the method for manufacturing the molecular film pattern described above. In the method for manufacturing the electro-optical device described above, since the method for manufacturing the molecular film pattern described above can be used instead of, for example, a photolithographic method, the number of steps can be decreased. Accordingly, this type of method for manufacturing the electro-optical device has advantages in that the production time or the production cost

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can be reduced.

A first electro-optical device of the present invention is manufactured by the method for manufacturing the electro-optical device described above.

A second semiconductor device of the present invention is formed by the manufacturing method described above and comprises an area composed of an organic material. As an example of a semiconductor device using an organic material, a so-called organic thin-film transistor may be mentioned. In the manufacturing process therefor, a liquid-phase process, such as a spin coating method or an inkjet method, which does not usually require a complicated apparatus, may also be used, and hence, advantage in production cost can also be obtained.

A second electro-optical device of the present invention is formed by the manufacturing method described above and comprises an organic electroluminescent element.

A method for manufacturing an electronic device of the present invention comprises a step performed by using the method for manufacturing the molecular film patterns described above. As the electronic device, a diode may be mentioned by way of example.

An electronic apparatus of the present invention comprises the electro-optical device described above as a display portion.

#### Brief Description of the Drawings

Fig. 1 is a cross-sectional view showing the state in which a molecular film is formed on a substrate.

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Fig. 2 is a cross-sectional view showing the state in which the molecular film is patterned.

Fig. 3 is a cross-sectional view showing a step of patterning the molecular film.

Fig. 4 is a cross-sectional view showing the state in which a second molecular film is formed in an area at which a first molecular film is removed.

Fig. 5 is a cross-sectional view showing the state in which an electroless plating film is formed on the area which is covered with the second molecular film.

Fig. 6 is a view showing a first step of manufacturing an organic electroluminescent device driven by an organic thin-film transistor.

Fig. 7 is a view showing a second step of manufacturing the organic electroluminescent device driven by the organic thin-film transistor.

Fig. 8 is a view showing a third step of manufacturing the organic electroluminescent device driven by the organic thin-film transistor.

Fig. 9 is a view showing a fourth step of manufacturing the organic electroluminescent device driven by the organic thin-film transistor.

Fig. 10 is a view showing a fifth step of manufacturing the organic electroluminescent device driven by the organic thin-film transistor.

Fig. 11 is a view showing a sixth step of manufacturing the organic electroluminescent device driven by the organic thin-film transistor.

Fig. 12 is a view showing a seventh step of manufacturing the organic electroluminescent device driven by the organic thin-film transistor.



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Fig. 13 is a view showing an eighth step of manufacturing the organic electroluminescent device driven by the organic thin-film transistor.

Fig. 14 is a view showing a ninth step of manufacturing the organic electroluminescent device driven by the organic thin-film transistor.

Fig. 15 is a view showing a tenth step of manufacturing the organic electroluminescent device driven by the organic thin-film transistor.

Fig. 16 is a view showing an eleventh step of manufacturing the organic electroluminescent device driven by the organic thin-film transistor.

Fig. 17 is a view showing a twelfth step of manufacturing the organic electroluminescent device driven by the organic thin-film transistor.

Fig. 18 is a view showing one application example in which an electro-optical device of the present invention is mounted on a mobile type personal computer.

Fig. 19 is a view showing one application example in which an electro-optical device of the present invention is mounted on a mobile phone.

Fig. 20 is a view showing one application example in which an electro-optical device of the present invention is applied to a viewfinder portion of a digital still camera.

[Reference Numerals]

11 substrate

11a liquidphilic portion

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- 11b liquid-repellent portion
- 14 molecular film
- 15 second molecular film
- 17 electroless plating film
- 19 photomask
- 20 substrate
- 21 transparent electrode
- 22 insulating film
- 23 light-emitting layer
- 24 cathode pattern
- 30 interlayer insulating film
- 31 via hole
- 32 interlayer wire
- 40 source
- 41 drain
- 42 semiconductor layer
- 43 gate insulating film
- 44 gate line
- 50 interlayer insulating film
- 55 source line

#### Embodiments

Hereinafter, preferred embodiments of the present invention will be described.

#### (1) Brief Explanation for Manufacturing Steps of Molecular Film and

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### Molecular Film Pattern

Manufacturing steps of a molecular film and a molecular film pattern will be described briefly with reference to Figs. 1 to 5.

First, as shown in Fig. 1, a molecular film 14 is formed on a surface of a substrate 11 by using an organic silicon compound containing an aromatic hydrocarbon group as a starting material. The molecular film 14 can be obtained by placing the organic silicon compound used as a starting material and the substrate in a closed container or by immersing the substrate in a solution containing the organic silicon compound used as a starting material followed by removal of the solvent.

Next, as shown in Fig. 2, patterning of the molecular film 14 is performed. As a patterning method for a molecular film according to the present invention, for example, a light irradiation method is performed. As shown in Fig. 3, a light irradiation method is performed by irradiating the molecular film 14 with a light via openings formed in a photomask 19 provided for forming a thin-film pattern. Parts of the molecular film 14 which are irradiated by light are decomposed or removed, and hence, a molecular film pattern in accordance with the photomask 19 is formed.

Furthermore, as shown in Fig. 4, only on the areas at which the parts of the molecular film 14 are removed, areas 15 composed of a molecular film may also be formed in which the molecular film mentioned above is formed by using an organic silicon compound as a starting material having a functional group provided with a property or a

(2) Example 1

As pretreatment, cleaning was performed by irradiating a quartz glass substrate with UV light having a wavelength of 172 nm for 10 minutes. The intensity of the UV light which was used was approximately  $8 \text{ mW/cm}^2$  at the surface of the substrate.

Next, (Heptadecafluorooctylbenzyl)triethoxysilane, having a superior liquid-repellent property and being one of organic silicon compounds having the chemical structure represented by the following formula (8), and a quartz glass substrate were kept in the same closed container at room temperature for 96 hours, thereby forming a first molecular film. Subsequently, in addition, the first molecular film is irradiated for approximately 15 minutes with ultra violet light (a light intensity at the quartz glass substrate was approximately  $5 \text{ mW/cm}^2$ ) having a wavelength of 308 nm using an excimer lamp via a photomask having a stripe pattern so that parts of the molecular film which are not covered with the mask are selectively photolyzed, thereby forming a first

When the contact angle at an area at which a molecular film was irradiated was observed for evaluating decomposition rate of a molecular film by irradiation, it was found that the decomposition rate of the first molecular film formed by using (heptadecafluorooctylbenzyl)triethoxysilane as a starting material was three times or more that of a molecular film formed by using (heptadecafluorotetrahydrodecyl)triethoxysilane as a starting material. According to this result, it was found that a molecular film formed by using an organic silicon compound containing an aromatic group, such as benzene, as a starting material exhibited an improved photolytic efficiency.

Next, the substrate provided with the first molecular film pattern and the second molecular film pattern was immersed for approximately 2 minutes in an aqueous solution containing palladium chloride so as to have a pH of 5.8 at room temperature (30 ml of an aqueous solution containing 4% of hydrogen chloride and 0.2% of a palladium salt was

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further dissolved in 1 liter of water for dilution) and was then washed using running water for 3 minutes. Next, an electroless nickel plating solution (having a composition containing 30 g/L of a nickel salt and a nickel salt of hypophosphorous acid and 10 g/L of sodium hypophosphite) having a pH of 4.6 was maintained at 70°C, and this substrate was then immersed in the solution described above for approximately 1 minute. Subsequently, the substrate was recovered from the solution, was washed by running water, and was then dried. After drying, when observation was performed by using an optical microscope, it was confirmed that a nickel pattern was formed on areas corresponding to the areas of the second molecular film pattern on the substrate.

In the present invention, in addition to a quartz glass substrate, as a substrate on which a molecular film is formed, various substrates, such as a Si wafer, glass, a plastic film, or a metal substrate, may be used, and on the surface of the substrate, a metal film, a dielectric film, an organic film, or the like may be formed as an underlying layer.

As a light source for irradiation used for forming a pattern of a molecular film, in addition to the excimer lamp described above, for example, a mercury lamp, a xenon lamp, a sodium lamp, an excimer laser, an Nd:YAG laser, or its higher harmonic wave may also be used.

As in the example described above, when a molecular film pattern having a liquid-repellent property is formed, an organic silicon compound having a long-chain fluoroalkyl group, such as (heptadecafluorooctylbenzyl)triethoxysilane which has a liquid-repellent property, is preferably used as a starting material; however, the

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compound having a general long-chain alkyl group may also be used. A substituent bonded to a silicon atom is not limited to an ethoxy group such as (heptadecafluorooctylbenzyl)triethoxysilane, and an alkoxyl group such as a methoxy group, a halogen group such as a chlorine, a bromine, or an iodine atom, or an amino group may also be used. In particular, the case in which the surface of a substrate or an underlying layer on which a molecular film is formed is covered with substituents having chalcogen atoms, such as hydroxyl groups, may be preferable in some cases. The reason for this is that when an organic silicon compound having the substituent bonded to the silicon atom described above forms a molecular film, the molecular film may form stable bond with the substrate or the underlying layer.

In the example described above, in order to selectively form an electroless plating film composed of nickel, an organic silicon compound having an amino group which has a high affinity to nickel was used as a starting material for forming the second molecular film; however, in addition to this compound described above, when a molecular film formed by using an organic silicon compound containing a thiol group, a hydroxyl group, a vinyl group, a hydrosilyl group, a cyano group, or the like is used as a starting material, various metal thin-films, such as gold or copper, may also be formed. Naturally, it is not always necessary to initially form a molecular film pattern having a liquid-repellent property as in the example described above, and a proper molecular film can be selectively formed in accordance with an object. When light-irradiation is used for the formation of a molecular film

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In the case in which light having a wavelength of approximately 300 nm is used for forming a molecular film pattern, an organic silicon compound containing an aromatic group, such as benzene, naphthalene, or biphenyl, is preferable as a starting material, and in the case in which light having a wavelength of 300 nm or more, an organic silicon compound containing an aromatic group, such as anthracene, phenanthrene, or terphenyl, is preferable as a starting material.

The efficiency of photolysis does not only depend on an aromatic group of an organic silicon compound but also may be affected by a substituent bonded to the aromatic group in some cases. For example, in an organic silicon compound having a trifluoromethyl group at the ortho-position of an alkyl group containing an organic silicon group, such as an organic silicon compound having a chemical structure represented by the above formula (11) or (12), since the fluorine atoms each having high affinity to the silicon atom are spatially adjacent thereto, activation energy required for breaking the bond between the silicon atom and the carbon atom decreases, and hence, a photolytic reaction occurs efficiently. In addition to a trifluoromethyl group, a substituent containing an atom having high affinity to a silicon atom,



(3) Synthesis of Organic Silicon Compound used as Starting Material for Molecular Film

(i) A reaction shown by the following general formula (13). This reaction occurs between an organic silicon compound containing a halogen atom or an alkoxyl group and a Grignard reagent obtained from a compound having a halogen atom, such as a bromine atom, a chlorine atom, or an iodine atom, or a lithium reagent.

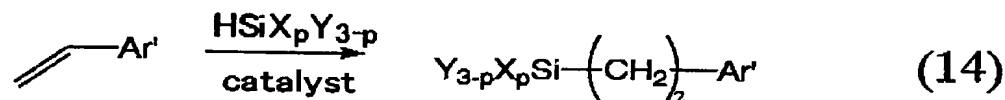
$$\text{Halogen}-(\text{CH}_2)_n-\text{Ar}' \xrightarrow[\text{Mg}]{\text{SiX}_{p+1}\text{Y}_{3-p}} \text{Y}_{3-p}\text{X}_p\text{Si}-(\text{CH}_2)_n-\text{Ar}' \quad (13)$$

$n$  is an integer of 0 or more;

Ar' is an aromatic hydrocarbon group or a derivative thereof.

(11) A hydrosilation reaction shown by the following general formula (14). This reaction occurs between a compound having a double bond or more between carbons and an organic silicon compound having at least one hydrogen atom bonded to the silicon atom by heating and

[Chemical 24]



Ar' is an aromatic hydrocarbon group or a derivative thereof.

(Compound A)

A magnesium ribbon is placed in a flask, and while an inert gas such as argon or nitrogen is allowed to flow therein, the ribbon is appropriately heated and also stirred by a hot plate which is also used as a stirrer, so that the magnesium ribbon (0.06 mol) is activated. After the operation described above is performed for approximately 1 hour, the flask is cooled to room temperature, and approximately 5 ml of ether is then added. In addition, by adding an extremely small amount of dibromoethane by using a syringe, an activated surface of the magnesium ribbon is exposed. Next, 20 ml of an ether solution containing 0.05 mol of  $\text{P}-(\text{CF}_3\text{CF}_2\text{CF}_2\text{CF}_2\text{CF}_2\text{CH}_2\text{CH}_2-\text{C}_6\text{H}_4-\text{CH}_2-\text{Br})$  and 0.07 mol of tetraethoxysilane is received in a dripping funnel provided for the flask, and while being well stirred, this ether solution is then

(5) Synthesis of p-(HMe<sub>2</sub>Si-CH<sub>2</sub>-C<sub>6</sub>H<sub>4</sub>-CH<sub>2</sub>-Si(OEt)<sub>3</sub>) (Compound B)

A magnesium ribbon is placed in a flask, and while an inert gas such as argon or nitrogen is allowed to flow therein, the ribbon is appropriately heated and also stirred by a hot plate which is also used as a stirrer, so that the magnesium ribbon (0.06 mol) is activated. After the operation described above is performed for approximately 1 hour, the flask is cooled to room temperature, and 5 ml of ether and 0.05 mol of dimethylchlorosilane (chemical formula:  $\text{HMe}_2\text{SiCl}$ ) are then added. Next, 0.05 mol of dimethylchlorosilane ( $\text{HMe}_2\text{SiCl}$ ) is added. Subsequently, 20 ml of an ether solution containing p-( $\text{Br}-\text{CH}_2-\text{C}_6\text{H}_4-\text{CH}_2-\text{Br}$ ) is received in a dripping funnel provided for the flask, and while being well stirred, this ether solution is then slowly dripped in the

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The synthetic route described below is almost equivalent to that for the compound A. That is, a magnesium ribbon is placed in a flask, and while an inert gas such as argon or nitrogen is allowed to flow therein, the ribbon is appropriately heated and also stirred by a hot plate which is also used as a stirrer, so that the magnesium ribbon (0.03 mol) is activated. After the operation described above is performed for approximately 1 hour, the flask is cooled to room temperature, and approximately 5 ml of ether is then added. Next, 20 ml of an ether solution containing 0.03 mol of  $p\text{-(HMe}_2\text{Si-CH}_2\text{-C}_6\text{H}_4\text{-CH}_2\text{-Br)}$  and 0.05 mol of tetraethoxysilane is received in a dripping funnel provided for the flask, and while being well stirred, this ether

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As described above, in particular, a synthetic method using a Grignard reagent is effectively applied to an organic silicon compound having an aromatic group which is provided with a fluoroalkyl group, an alkyl compound group, an organic silicon group, an alkoxy group, or the like. Even though a yield is naturally decreased a little bit, in a manner as described above, a compound such as shown by the formula 11 or 12, which has a trifluoromethyl group at the ortho-position of the compound A, can also be obtained. In addition, in the case in which an organic silicon compound provided with a substituent, such as a hydroxy group, a thiol group, an amino group, or a cyano group, having highly reactivity with a Grignard reagent is synthesized on an aromatic group,

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a so-called hydrosilation (the method (ii) described above) performed between corresponding olefin and hydrosilane is effective.

(6) Production of Electroluminescent Device Driven by Organic Thin-Film Transistor

By using the molecular film and the molecular film pattern described above, various semiconductor devices and the electro-optical devices can be further produced. In the examples described below, an organic thin-film transistor having an active layer formed of an organic material and an organic electroluminescent device driven by this organic thin-film transistor will be described as a semiconductor device and an electro-optical device, respectively, with reference to the manufacturing steps thereof. Figs. 6 to 16 are views showing manufacturing steps of an organic thin-film transistor and an organic electroluminescent device driven by this organic thin-film transistor. Between two drawings in each figure, the drawing on the right side is a plan view, and the drawing on the left side is a cross-sectional view taken along the line AA in the plan view.

First, a transparent conductive film 21 is formed on a substrate 20. As the substrate 20, a transparent material composed of, for example, glass, quartz, or plastic (synthetic resin), is used. In addition, as the transparent conductive film 21, ITO (indium tin oxide) is preferable. However, it is not limited to an ITO film, and another material may also be used as long as the material is transparent and has high conductivity. In this embodiment, a glass provided with an ITO film is used.

Next, in order to prevent a leak current flowing between a cathode

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pattern 24 (Fig. 9), which will be described later, and the transparent conductive film 21, an insulating film 22 is formed on the transparent conductive film 21. In this embodiment,  $\text{SiO}_2$  is used. As a starting material, a liquid material containing polysilazane dissolved in xylene is used, the formation is performed by an inkjet (I/J) method only in an area other than that of a cylinder-shaped opening which is used as a light-emitting area. After the solution containing polysilazane is applied by an I/J method, heating at  $250^\circ\text{C}$  for 10 minutes is performed, thereby selectively forming a  $\text{SiO}_2$  film having a desired shape and a thickness of 150 nm. In addition, as long as the insulating properties are ensured, the material is not limited to that described above, and an organic polymeric material such as a polyimide resin may also be used.

Next, a light-emitting layer 23 may be formed of two layers, that is, a hole injection layer for hole injection and an electroluminescent layer for light emission. Both materials may be formed by using an I/J method. The formation may be performed by using spin coating, deposition, or the like.

Next, the light-emitting layer 23 is formed on the transparent conductive film 21 in an area defined by the insulating film 22. In this embodiment, a cylinder-shaped opening is provided in the insulating film 22 so that the inside periphery thereof is round in plan view, and the light-emitting layer 23 is formed selectively in this opening by an I/J method. In particular, a solution containing a polyolefinic polymer dissolved in xylene used as a solvent is prepared, the solution is applied by an I/J method, and the solvent is dried and removed, thereby

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forming the light-emitting layer 23. In this embodiment, the thickness of the light-emitting layer 23 is set to approximately 80 nm. In addition, as the light-emitting layer, an organic electroluminescent material such as polyparaphenylene vinylene (PPV) may also be used.

Next, the cathode layer pattern 24 is formed on the insulating film 22 and the light-emitting layer 23 using a metal material. As the metal material, for example, gold, silver, or copper may be used. This cathode layer pattern 24 may be formed by an I/J method or by, for example, a deposition method. In this embodiment, a solution containing a gold complex dissolved in an ethanol solution is used. In particular, as the gold complex, a material represented by  $(CH_3)_3P-Au-CH_3$  is used, the concentration thereof is set to approximately 2 wt%, and a solution containing this material is applied by an I/J method and is then heated to 80°C, thereby forming a 50 nm-thick gold film pattern having superior conductivity.

Subsequently, an interlayer insulating film 30 is formed on the cathode layer pattern 24. As the interlayer insulating film 30, for example, polyvinyl alcohol (PVA) or polyimide, which are polymeric materials, may be used. In addition to those, an inorganic material such as  $SiO_2$  may also be used. When a polymeric material is used for forming the interlayer insulating film 30, the film formation may be performed by, for example, spin coating or an I/J method. In this embodiment, a PVA solution is applied by a spin coating method, thereby forming a PVA film of 1.5  $\mu m$  in thickness.

Next, a via hole 31 is formed in the interlayer insulating film 30



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As a material for the source 40 and the drain 41, for example, a metal or a conductive polymeric material may be used. The source 40 and the drain 41 are each formed by selectively forming a film by an I/J

In addition, an organic semiconductor layer 42 is formed on the source 40 and the drain 41 (Fig. 14). This organic semiconductor layer 42 may be formed by spin coating, deposition, an I/J method, or the like using an organic material. In this embodiment, a starting material in the liquid form containing anthracene dissolved in xylene is spin coated, so that an organic semiconductor film composed of anthracene is formed. The thickness thereof is 200 nm. As a material for forming an organic semiconductor film, in addition to a fused polycyclic aromatic group such as tetracene or pentacene, a conjugated oligomer or polymer, such as hexathienylene, oligothiophene, or polyacetylene, may also be used.

Next, a gate insulating film 43 is formed on the organic semiconductor layer 42. For this gate insulating film 43, the same material as that for the interlayer insulating film 30 may be used. In this embodiment, by using a PVA film, a thickness of 1  $\mu\text{m}$  is formed by spin coating. In addition, as shown in Fig. 15, a gate line 44 is formed so as to cover corner portions of the source 40 and the drain 41. This gate line 44 is formed by a coating method using a toluene solution containing a liquid gold-based material as in the case of the source 40 and the drain 41. As a solvent for this liquid gold-based material, toluene is used. The thickness of the gold film thus formed is approximately 50 nm.

In this embodiment, the formation of an organic electroluminescent element is performed prior to the formation of an organic thin-film transistor; however, the formation of an organic thin-film transistor may first be formed. In the case described above, a molecular film

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formed of an organic silicon compound having an aromatic hydrocarbon group may also be used for forming a via hole.

In this embodiment described above, the organic thin-film transistor is formed by using a method for manufacturing a molecular film pattern of the present invention; however, it is apparent that the method for manufacturing the molecular film pattern of the present invention is effectively applied to the production of transistors, which are generally used, that is, is effectively applied to the production of silicon-based transistors or thin-film transistors (TFT) formed on insulating substrates.

In conclusion, conventional steps using a photolithographic method for manufacturing semiconductor devices, electronic devices, electro-optical devices, and the like can be basically performed by using the manufacturing method for the molecular film pattern, the manufacturing method for the semiconductor devices, and the manufacturing method for the electro-optical devices according to the present invention.

Next, several examples of electronic apparatuses to which the electro-optical device described above is applied will be described. Fig. 5 is a perspective view showing the structure of a mobile personal computer to which the electro-optical device described above is applied. In this figure, a personal computer 1100 has the structure composed of a display unit 1106 and a main body 1104 provided with a keyboard 1102. The display unit 1106 comprises the electro-optical device 100 described above.

Fig. 6 is a perspective view showing the structure of a mobile

Fig. 7 is a perspective view showing the structure of a digital still camera provided with the electro-optical device 100 shown in Fig. 7 which is used for a viewfinder of the camera. In this figure, the connection with external apparatuses is also briefly shown. Compared to a general camera which exposes a film using an optical image of an object, a digital still camera 1300 produces image signals by performing photoelectric conversion of an optical image of an object using an imaging element such as a CCD (Charged Coupled Device). The electro-optical device 100 described above is provided on the back surface of a case 1302 of the digital still camera 1300 so as to perform display in accordance with the image signals provided from the CCD, and the electro-optical device 100 serves as a viewfinder for displaying the object. In addition, a light-receiving unit 1304 containing an optical lens, the CCD, and the like is provided on an observing side (the back surface side in the figure) of the case 1302.

When a picture taker views an object image displayed on the electro-optical device 100 and then presses a shutter button 1306, an image signal of the CCD at that time is transferred to and stored in a memory of a circuit substrate 1308. In addition, in this digital still camera 1300, a video signal output terminal 1312 and an input/output

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terminal 1314 for data communication are provided on the side surface of the case 1302. As shown in the figure, when it is necessary, the former, i.e., the video signal output terminal 1312, and the latter, i.e., the input/output terminal 1314 for data communication, are connected to a television monitor 1430 and a personal computer 1430, respectively. Furthermore, the structure is formed so that the image signal stored in the memory of the circuit substrate 1308 is output on the television monitor 1430 or to the personal computer 1440 by a predetermined operation.

As an electronic apparatus to which the electro-optical device 100 of the present invention can be applied, in addition to the personal computer shown in Fig. 5, the mobile phone shown in Fig. 6, and the digital still camera shown in Fig. 7, there may be mentioned a television, a viewfinder type and a direct viewing video tape recorder, a car navigation apparatus, a pager, an electronic notebook, an electronic calculator, a word processor, a workstation, a television phone, a POS terminal, an apparatus provided with a touch panel, or the like. Accordingly, the electro-optical device 100 is naturally applied to display units of the various electronic apparatuses described above.

#### [Advantages]

According to the present invention described above, a patterning technique which can easily form a molecular film pattern at a high speed can be obtained, and the number of steps of manufacturing semiconductor devices or electro-optical devices and the cost thereof can be decreased.